

Topology of gold nanoparticle distribution and optical properties of opal-based metal-dielectric photonic crystals

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So far no omnidirectional photonic bandgap (PBG) in the visible have been achieved with metal-dielectric (MD) photonic crystals (PhCs). Here we summarize our observations of opal-based 3D MD PhCs containing Au nanoparticles comparing opals from Au nanoshells, opals with interstitial Au nanoshells and inverted opals from Au nanoparticles and outline their prospects.

In all cases, reflectance spectra exhibit the surface plasmon (SP) resonance and the diffraction resonance. We found that achieving the goal of modifying the diffraction resonance requires (i) formation of metal nanoshells and (ii) overlap of diffraction and nanoshell SP resonances. In the Au nanoparticle inverted opal, the SP and diffraction resonances cannot interact because nanoparticles themselves are not involved in scattering at PBG relevant frequencies. Alternatively, if the SP resonance in nanoshells does not overlap with the diffraction resonance, the PBG structure remains similar to that of all-dielectric opal with the dielectric constant modified by Au nanoparticles. The anti-crossing of diffraction and nanoshell SP resonances has been observed when Au nanoshells become major scatterers comprising the PhC lattice. In this case, specific excitations in the PBG frequency range will probably occur due to the high polarizability of nanoshells.

Ultra-short InP-based polarization rotator

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Asymmetric rib waveguides have been employed to produce compact ($\sim 300\mu\text{m}$) polarization converters [1]. We extend this idea and use slanted slots deeply etched in the middle of the ridge waveguide in the direction of light propagation (Fig. 1 a). This allows us to achieve efficient polarization conversion over very short (several micron long) devices. We report polarization conversion of about 90% (Fig. 1 b) utilizing 2- μm long deeply etched 1-D photonic crystals in InP-based material.

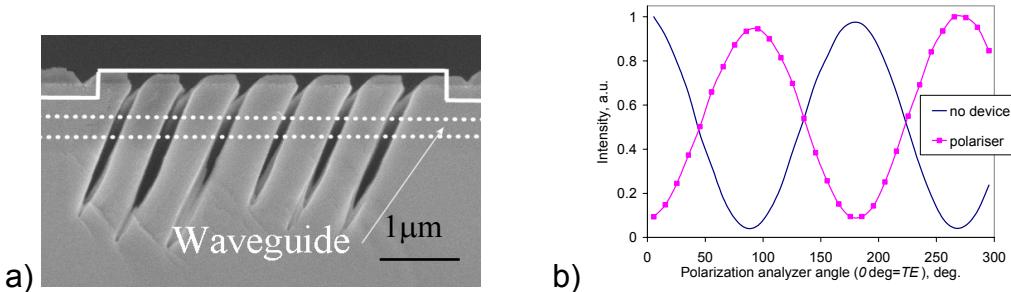


Fig. 1. a) SEM image of deeply etched 100-nm wide slanted slots. Bold white line schematically represents the cross section of shallow etched ridge waveguide; b) intensity of the output-light versus polarization analyzer angle.

- [1] H. El-Refaei, D. Yevick, and T. Jones, *IEEE J. Lightwave Technol.*, **22**, 1352 (2004).

Dispersion of defect modes in silicon photonic crystal waveguides measured by attenuated total reflectance

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The dispersion of defect modes in linear photonic crystal (PhC) waveguides defined on Silicon membranes is measured all over the guided mode region of the Brillouin zone by means of angle- and polarization- resolved attenuated total reflectance (ATR). The use of a silicon prism for ATR (unlike in previous measurements on SOI systems with a ZnSe prism: M. Galli et al., Phys. Rev B 70, 081307R, 2004) greatly enhances the coupling to guided photonic modes with high group velocity. The presence of a single-mode window in the guided region is demonstrated for standard W1.0 waveguides (a missing row of holes in the Γ K direction of the triangular lattice) as well as for W1.5 waveguides with increased channel width. This finding may be important for the realization of linear PhC waveguides with ultra-low losses. The experimental results are successfully compared with full 3D calculations of the photonic mode dispersion as well as of ATR spectra.

Selection Rules for Light Scattering by Localized Eigenmodes of the Menger Sponge Fractal

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An effort to localize electromagnetic (EM) waves in a three-dimensional fractal was reported recently [1,2]. It was claimed that a quality (Q) factor as large as 610 was observed by an experimental study of microwave transmission and reflection for the Menger sponge fractal made of an epoxy resin with dielectric constant of 2.8. However, there was an ambiguity in the interpretation of the experimental data and the Q factor of 610 was an apparent overestimation. However, as I will show in this presentation, localized EM modes with the Q factor of several hundreds can certainly be realized in the Menger sponge when the dielectric constant is increased to 8.8 (mixture of epoxy resin and metal oxides). I will show this by the numerical simulation of dipole radiation based on the FDTD (finite-difference time-domain) method. The eigenfrequencies, Q factors, and field distributions of the localized modes will be presented. In addition, the selection rules for the 90-degree light scattering due to the symmetry of the eigenmodes will be derived and compared with the calculated spectra.

- [1] M. Wada-Takeda et al., *Phys. Rev. Lett.*, **92**, 093902 (2004).
- [2] M. Wada-Takeda et al., *Technical Digest of PECS-V*, 85 (2004).

Understanding Cavity-QED and Disorder in Planar Photonic Crystals: Exploiting the Photon Green Function

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Love them or hate them, photon Green functions have a very special role to play in unraveling some of the complexities and mysteries of photonic crystal (PC) science. How to describe genuine quantum optical effects? How to include fabrication imperfections? From an intuitive theoretical perspective, we will introduce, discuss and example several photon Green function techniques that allow one to study a variety of increasingly important optical effects in planar PCs in a remarkably elegant way. We will address both practical (*and potentially profound*) problems and intriguing light-matter interaction regimes, including the role of fabrication disorder in PC waveguides and cavities [1], and cavity-QED with single [2] and several quantum dots [3] in nanocavities.

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- [1] S. Hughes *et al.*, *PRL*, **94**, 33903 (2005); E. Kuramochi *et al.*, *PRL*, Submitted.
- [2] S. Hughes, *Opt. Lett.* **29**, 2659 (2004); S. Hughes, *Opt. Lett.*, In press (2005); T. Yoshie *et al.*, *Nature* **432**, 200 (2004); S. Hughes & H. Kamada, *PRB* **70**, 195313 (2004).
- [3] S. Hughes, *PRL*, In press (2005).